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SYSTEM SAFETY CONSIDERATIONS FOR THE DESIGN OF A CHEMICAL SURETY MATERIEL LABORATORY

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PREFACE

This document was prepared to show, through example, how established system safety concepts can be applied to the design of a chemical surety materiel (CSM) laboratory. The end result of this effort was the development of safety considerations for incorporation into the design of a CSM laboratory.

REFERENCES

1. Draft Technical Manual, TM XX-XX, Undated, Facility System Safety Program.

2. CSL SOP 70-18, 10 Nov 82, Exhaust Ventilating Systems.

3. DOD 6055.9 - STD, July 1984, Ammunition and Explosives Safety Standards.

4. DARCOMR 385-102, 6 May 1982, Safety Regulations For Chemical Agents GB and VX.

5. CSL SOP 385-1, 2 June 1982, Chemical and Occupational Safety and Health Program.

..0. INTRODUCTION: The application of system safety concepts to the facility acquisition process has recently gained acceptance throughout the Department of Defense and most recently within the the Department of Army with the conception of SAFEARMY 1990. The Army's goal is to: "fully integrate the total system safety, human factors, and health hazard assessments into continuous comprehensive evaluation of selected systems and facilities." The Chemical Research Development and Engineering Center (CRDEC) has mandated appropriate levels of system safety throughout the lifecycle of facility development for many reasons. These include:

* Optimum safety and health is required to prevent personnel injury to these agents. Facility System Safety (FSS) is one avenue used to achieve optimum safety and health in our operations.

* FSS is a proven method to reduce deficiencies during facility acquisition.

* FSS is a proactive approach which will reduce inconsistencies found in our facilities thereby reducing outside scrutiny.

This article demonstrates one specific effort in (Facility System Safety) (FSS) currently underway at CRDEC. The intended purpose of this article is to demonstrate, through specific examples, how FSS can be applied to the design/construction/operation of a chemical surety materiel laboratory. The laboratory under study is a 32 million dollar Military Construction, Army (MCA) project designed to replace aging facilities which are currently utilized to perform daily CSM operations. This article will demonstrate the methods used in identifying, analyzing and ultimately eliminating or reducing the effect of a hazard on the facility, equipment and personnel.

2.0. FACILITY SYSTEM SAFETY OVERVIEW: The process of applying system safety to facility acquisition can be divided into the following tasks:

a. Categorization

b. Preliminary Hazard List

c. Preliminary Hazard Analysis

d. Design Considerations

The remainder of this article will involve a description of each of these tasks followed by an example of how the task was applied to the design of this CSM laboratory. Descriptions of tasks a-c were taken from reference 1.

3.0. CATEGORIZATION: The first step in this process is to clearly define the risk associated with the operation of this laboratory. This step includes a brief description of the operation followed by a risk assessment and a recommendation on the level of system safety required.

3.1. LABORATORY DESCRIPTION: The laboratory under consideration will conduct diversified chemical surety materiel laboratory operations. These materials are anticholinergic agents and are extremely lethal in small concentrations.

The recommended permissible airborne exposure concentration for these agents are in the area of 0.0001 mg/m3(2 x 10-5ppm). Two personnel are required, as a minimum, to perform this operation.

3.2. ASSESSMENT: The most significant hazard present in this laboratory operation is the release of vapor CSM from engineering controls and into the workplace. This mandates further efforts in system safety in the form of a Preliminary Hazard List (PHL) and a Preliminary Hazard Analysis (PHA). The user must in this instance take an active role in the design review process.

4.0. PRELIMINARY HAZARD LIST: Once the risk categorization is completed, the next step is to develop a PHL.

4.1. PURPOSE: The PHL is a user generated listing of hazards which must be controlled. The user must at this stage assign a risk assessment code to each hazard and establish any further requirements for analyses. As a minimum the user should use the following sources of information for PHL development:

a. Material Safety Data Sheets

b. Feasibility Studies

c. Project Development Brochures

d. Standing Operating Procedures

e. Operator Interviews

4.2. PRELIMINARY HAZARD LIST DESCRIPTION: The incorporation of this information into a PHL entry is shown as Figure 2. This entry describes; the nature of the hazardous event (column 1), why or how the hazard may result in a mishap (column 2), the effects on operating personnel, equipment, and the facility (column 3), the risk assessment code assigned to the uncontrolled hazard (column 4) and any comments the originator may have (column 5).

5.0. PRELIMINARY HAZARD ANALYSIS: The next step in the process is the development of a PHA. This analysis is the core of the FSS program and as such is vital in eliminating or reducing the inherent hazards associated with this laboratory operation.

5.1. PURPOSE: The PHA is used to further analyze the data identified in PHL. This enhances the hazard control database and provides specific recommended corrective action for the resolution of hazardous conditions. combination of the informational sources used in the PHL development and any additional design information should be used in PHA development.

5.2. PRELIMINARY HAZARD ANALYSIS DESCRIPTION: The incorporation of this information into a PHA entry is shown as Figure 3. This entry describes; the proposed actions needed to eliminate or control the hazard (column 6), the risk assessment code assigned after controls (column 7), and the identification of applicable codes and standards (column 8).

5.3. HAZARD TRACKING LOG: In addition to the above analysis, a hazard tracking log should be maintained. This log is to ensure all open loops are

closed and ensures the appropriate level of management is identified as being involved in the acceptance of risk. This log should be initiated during the design phase and maintained throughout the construciton portion. A simulated entry is shown in Fig. 4. This entry describes; the specific action taken to eliminate, control or accept the hazard (column 9), the reference of the blueprint/drawing numbers or other documents that address the action taken (column 10), name of individual closing out the action on design (column 11), and the name of the individual closing out the action during construction (column 12). The information contained in this log does not reflect an actual log entry but is shown for information purposes only.

6.0. LABORATORY DESIGN CONSIDERATIONS: As a result of this effort, detailed safety design considerations can be developed to preclude the release of lethal concentrations of vapor CSM into the workplace. This will minimize the potential for death or serious injury to our research scientists. A summary of these requirements is shown in Appendix A.

7.0. CONCLUSIONS: The effort put forth in FSS for this laboratory has many benefits. Most noteworthy are:

a. Safest possible laboratory

b. More mission responsive facility

c. Less expensive facility

This article is a step in the direction we must all head towards and that is total system safety for facilities to reduce inherent hazards associated with their operation.

Risk Assessment. An expression of possible loss, described in terms of hazard severity and mishap probability. Subdefinitions follow:

A. Hazard. Any existing or potential condition that can result in a mishap.

B. Mishap. An unplanned event or series of events that result in death, injury, occupational illness, or damage to or loss of equipment or property (i.e., an accident).

C. Hazard severity. An assessment of the worst potential consequence, defined by degree of injury, occupational illness, or property damage which could occur. Hazard severity categories will be assigned by Roman numeral according to the following criteria:

(1) Category I - Catastrophic: May cause death or loss of a facility.

(2) Category II - Critical: May cause severe injury, severe occupational illness, or major property damage.

(3) Category III - Marginal: May cause minor injury, minor occupational illness, or minor property damage.

(4) Category IV - Negligible: Probably would not affect personnel safety or health, but is nevertheless in violation of specific standards.

D. Mishap Probability. The probability that a hazard will result in a mishap, based on an assessment of such factors as location, exposure in terms of cycles or hours of operation, and affected population. Mishap probability will be assigned an arabic letter according to the following criteria:

(1) Subcategory A - Likely to occur immediately.

(2) Subcategory B - Probably will occur in time.

(3) Subcategory C - May occur in time.

(4) Subcategory D - Unlikely to occur

E. Risk Assessment Code. An expression of risk which combines the elements of hazard severity and mishap probability (e.g., IA, IIIB, etc.). The following table gives the rank order risk assessment codes.

		Mishap Probability			
		A	B	C	D
Hazard Severity	I	1	1	2	3
	II	1	2	3	4
	III	2	3	4	5
	IV	3	4	5	5

F. Imminent Danger. A hazardous situation for which risk assessment code of category IA, IIA, or IB has been assigned.

Figure 1. RISK ASSESSMENT

COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5
HAZARDOUS EVENTS	CAUSAL FACTORS	EFFECTS	RISK ASS. CODE	COMMENTS
Release of vapor CSM from lab hood and into workplace or atmosphere	1. Power failure	1. Loss or lab hood capture. Release of CSM into workplace. Personnel injury or death. System/ facility damage minimal.	I A 1	None
	2. Mech. exhaust fan failure	2. Same as #1 above	I B 1	None
	3. Poor lab hood capture (Design)	3. Turbulence may result in small release of CSM into workplace. Personnel injury or death could result. System/facility damage minimal.	I B 1	None
	4. Operator error	4. Judgement errors could result in an inadvertent release of CSM into the workplace. Personnel injury or death could result. System/facility damage minimal.	I B 1	None
	5. Filters do not remove CSM from exhaust	5. Personnel injury to people surrounding the facility. System/facility damage minimal. Adverse publicity.	II C 3	Scenario less likely and severe due to dilution factor.
	6. Exhaust ductwork not properly sealed	6. Small concentrations CSM in the workplace possible in the event the exhaust system were to go positive. Personnel injury or death possible. System/facility damage minimal.	I C 2	Scenario less likely due to additional requirement for system to go positive.

FIGURE 2 - PRELIMINARY HAZARD LIST

COLUMN 5 RECOMMENDED ACTIONS	COLUMN 6 CONTROLLED RISK ASS. CODE	COLUMN 7 STANDARDS
CAUSAL FACTOR #1: a.) Emergency generator system shall be installed to automatically initiate in the event of a power failure, system phasing shall be accomplished in a manner which will not permit the occurrence of a hazardous condition. b.) Laboratory hoods must be equipped with a mechanism to warn operators of emergency power status and hood function. c.) Standing Operating Procedures should contain provisions for the curtailment of operations, immediate masking and evacuation from areas that experience power failures.	IV D 5	DOD 6055.9-STD DARCOMR 385-102 CSL SOP 385-1
CAUSAL FACTOR #2: a.) Two alternatives are available to prevent a hazardous condition from occurring in the event of a mechanical failure. These include: (1) Redundant exhaust fan units, (2) Procedural controls which require curtailment of operations, donning of protective masks and immediate evacuation during ventilation loss. b.) Laboratory hoods shall be equipped with a means to warn operators of improper ventilation system functioning	IV D 5	DOD 6055,9-STD DARCOMR 385-102 CSL SOP 385-1 LOCAL SOPs
CAUSAL FACTOR #3: a.) Laboratory hoods must be located away from: -Main traffic aisles and doorways -Adjacent walls and operable windows -Cross drafts exceeding 30 lfpm -Heating Units -Exits. b.) Laboratory hoods must perform as follows: -Average inward face velocity of 100 lfpm +/- 10% with the velocity at any point not deviating from the average face velocity by more than 20%	IV D 5	DARCOMR 385-102 AEHA Technical Guide #30 CSL SOP 385-1

FIGURE 3. PRELIMINARY HAZARD ANALYSIS

COLUMN 5	COLUMN 6	COLUMN 7
RECOMMENDED ACTIONS	CONTROLLED RISK ASS. CODE	STANDARDS
CAUSAL FACTOR #3 (Continued):		
c.) Operators must be trained in proper operation within a laboratory hood.		
CAUSAL FACTOR #4:	IV D 5	CSL SOP 385-1
a.) Operating personnel must be properly trained. b.) Operating personnel must wear appropriate protective clothing. c.) Operating personnel must work under a properly approved SOP.		
CAUSAL FACTOR #5:	IV D 5	CSL SOP 70-18 CSL SOP 385-1
a.) Exhaust filtration system shall meet CSL SOP 70-18.		
CAUSAL FACTOR #6:	IV D 5	DOD 6055.9-STD CSL SOP 385-1
a.) Ductwork shall be sealed to preclude leakage. b.) All joints shall be seamless welded. c.) Ductwork shall be capable of withstanding 16 inches water column vacuum and 25 inches water column positive pressure.		

FIGURE 3 - PRELIMINARY HAZARD ANALYSIS
(Continued)

COLUMN 8 ACTION TAKEN	COLUMN 9 TRANSFER	COLUMN 10 DESIGN CERTIFICATION	COLUMN 11 CONSTRUCTION CERTIFICATION
CAUSAL FACTOR #1:			
a.) Emergency generator installed and properly phased	Drawing #:099 Specification Section # 09991	Mr. Smith	Mr. Jones
b.) Laboratory hoods equipped with warning devices to notify operator of power loss	Drawing #:061 Specification Section # 08001	Mr. Smith	Mr. Jones
c.) Installation notified of finding	Disposition Form sent 6 Jan 86 to safety office	-----	-----
CAUSAL FACTOR #2:			
a.) Installation safety office determines need to go with procedural controls. SOPs will be developed accordingly.	Disposition Form 10 Jan 86	-----	-----
b.) Laboratories equipped with warning devices to notify operators of ventilation system failure	Drawing #:061 Specification Section # 08001	Mr. Smith	Mr. Jones
CAUSAL FACTOR #3			
a.) Lab hoods meet the following: Away from: -Main traffic aisles -Doorways and Windows -Adjacent walls -Cross drafts > 30 lfpm -Heating units -Exits	Drawning #:045	Mr. Smith	Mr. Jones

FIGURE 4. HAZARD TRACKING LOG

COLUMN 8	COLUMN 9	COLUMN 10	COLUMN 11
ACTION TAKEN	TRANSFER	DESIGN CERTIFICATION	CONSTRUCTION CERTIFICATION
CAUSAL FACTOR #3 (Continued)			
b.) Lab hoods perform as follows: -Average face velocity 100 lfpm +/- 10%. No single reading deviating from average by 20% -Smoke testing did not result in a release of visible smoke	Drawing #:046 Specification Section # 07010	Mr. Smith	Mr. Jones
c.) Installation notified of requirement for proper training of operators	Disposition form dated 25 Mar 86	-------	-------
Causal Factor #4			
Installation responsibility	Installation notified 25 Mar 86	----------	--------
Causal Factor #5			
Exhaust system complies with CSL SOP 70-18	Specification Section # 01001	Mr. Smith	Mr. Jones
Causal Factor #5			
Ductwork properly sealed and tested	Specification Section # 02000	Mr. Smith	Mr. Jones
	Disposition form dated 25 Mar 86	---------	---------

FIGURE 4. HAZARD TRACKING LOG
(CONTINUED)

APPENDIX A

Laboratory Design Considerations

For

Protection Against Vapor CSM Exposure

A. Electrical Design Considerations (Causal Factor #1):

1. Emergency generator systems will be installed to service the following:

-Exhaust ventilation fans

-Make-up air handling units

-Critical operating equipment

-Emergency lighting

-All emergency alarm systems

2. Diesel-powered generators will be used. The emergency generator will be sized to handle 100% of the connected emergency load.

3. Start-up of the exhaust ventilation system and critical equipment must be sequenced to prevent a hazardous condition. In addition, the starting of the supply air handling unit and the exhaust fan services each room shall initiate simultaneously to avoid placing the room under positive pressure. Automatic transfer switching will be used.

B. Warning Systems (Causal Factor #1&2):

1. Facility will be equipped with a master control panel and alarms which permits functional verification of the exhaust blowers, filters, make-up air supply systems, fire control systems and waste treatment processes.

2. Laboratory hoods will be equipped with audible and visual alarms which will be designed to initiate when the average inward face velocity falls below 90 linear feet per minute.

3. Visible alarms must be located so they can be readily seen by personnel while working at the exhaust hood.

4. A test switch must be installed on all alarms which will permit the operator to verify that the light has not burned out and the sound alarm will function. This test must be performed while ventilation system is in full operation.

C. Laboratory Hood Location (Causal Factor #3):

1. Laboratory hoods must be located away from:

- Heavy traffic aisles
- Doorways
- Adjacent walls
- Crossdrafts that exceed 30 lfpm
- Heating units
- Exits

2. Sidewall registers and conventional ceiling diffusers shall not be used for laboratory air supply.

3. Perforated ceiling panels shall be used so that distribution of supply air is three feet minimum from the front face of the hood. The exit velocity from these panels shall not exceed 30 lfpm.

D. Laboratory Hood Performance (Causal Factor #3):

1. Laboratory hoods shall have an average inward face velocity of 100 lfpm +/- 10% with the velocity at any point not deviating from the average face velocity by more than 20%.

2. Leakage testing must be done with 30 second or one minute smoke candles placed approximately 20 centimeters inside the hood. Any visible escape of smoke should be considered indicative of unacceptable performance.

3. Laboratory hoods shall be designed as deep and low in height as practical. Rough wall surfaces and recesses in walls and work surfaces are unacceptable.

4. The location of sash tracks and the number of baffles and slots provided are integral to the proper containment of materials.

5. Laboratory hoods will be equipped with a 20 centimeter line taken from the face of the hood. No CSM contaminated equipment should be placed in front of this line during operations.

E. Exhaust Ventilation/Filtration System (Causal Factor #5):

1. All laboratory exhaust air shall be exhausted through a filtration system which complies with CSL SOP 70-18. These systems have been proven to be effective in removing CSM vapor from an exiting airstream.

2. Ventilation exhaust shall not be recirculated.

3. Instrumentation shall be required to monitor and control the airflow through the filter system. Instrumentation shall provide a means to monitor overall pressure drop as well as the pressure drop between each filter element.

4. The filter system shall include a series redundant-parallel Chemical Biological Radiological (CBR) filter assembly with a capability of placing a detector between the adsorber banks to warn of "breakthrough". The system shall provide accessibility to filters for repairs, maintenance and leak testing.

5. The filter system shall be as follows:

Hood-- Prefilter-- HEPA-- Adsorber-- Adsorber-- HEPA-- Exhaust

6. Exhaust stacks shall be designed and constructed to ensure good dispersion of exhaust air to the atmosphere thereby preventing recirculation.

F. Exhaust Ductwork (Causal Factor #6):

1. All ductwork shall be round, and welded with flange connections.

2. All ductwork shall be capable of withstanding 16 inches water column vacuum and 25 inches water column positive pressure.

3. Ductwork shall be designed to facilitate dismantling and to minimize the release of contamination to adjacent areas with bagging or other approved means.